

(19) Japan Patent Office (JP)

(11) Japanese Unexamined Patent
Application Publication Number

**(12) Japanese Unexamined Patent
Application Publication (A)**

S59-19912

(51) Int. Cl. ³	Identification codes	JPO file numbers	(43) Publication date: February 1, 1984
G 02 B 7/11		7448 - 2H	No. of Inventions: 1
G 01 N 21/01		7458 - 2G	Request for examination: Not yet requested
G 02 B 21/00		7370 - 2H	

(Total of 4 pages)

(54) LIQUID IMMERSION DISTANCE HOLDING APPARATUS

(21) Japanese Patent Application No.:	S57-129065	Hitachi, Ltd. Central Research Laboratory 1-280 Higashikoigakubo, Kokubunji-shi
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Specification

1. Title of the Invention

Liquid Immersion Distance Holding Apparatus

2. Scope of Patent Claims

(1) A liquid immersion distance holding apparatus that positions and holds a sample at the focus position of an optical system in an optical apparatus for observing the sample in a liquid or projecting an image to the sample in a liquid; characterized in that it is comprised by being provided with a detection system including a detector that has nearly the same shape as the optical path between the member of the optical system and the sample at the lower end part of the lens barrel of the optical system and a suction system path or a supply system path that sucks in or supplies the liquid from the opening part of the detector by means of a suction source or supply source, a piezoelectric transducer that detects pressure within the detector that corresponds to the distance between the detector and the sample and outputs an electrical signal, and a movement control mechanism that positions and holds the sample at the focus position using the output of the piezoelectric transducer.

(2) A liquid immersion distance holding apparatus described in Claim 1; wherein the detection system comprises a reference unit that has a flow rate resistance equivalent to that of the opening part of the detector and that has a suction system path or a supply system path with flow rate resistance equivalent to that of the suction system path or the supply system path for the liquid from the detector, and the movement control mechanism comprises an amplification control circuit that inputs the output of the pressure transducer, and drive control of the movement control mechanism is performed so that the reference unit and the detector are connected to the same suction source and the pressure differential of the reference pressure within the reference unit and the detection pressure within the detector becomes a constant value.

(3) A liquid immersion distance holding apparatus described in Claim 2; wherein the amplification control circuit has a configuration with which is possible to apply a prescribed voltage from an external circuit, and it is possible to drive the movement control mechanism by means of the applied voltage, and it is possible to set the sample at the desired position.

3. Detailed Explanation of the Invention

The present invention relates to a liquid immersion distance holding apparatus for performing positioning and holding of the sample in a liquid immersion type optical apparatus and particularly to a distance holding apparatus that is optimal for the autofocusing of exposure apparatuses that project a pattern to a sample in a liquid.

In an optical apparatus for observing or projecting a pattern using an optical lens, increasing the numerical aperture NA is well known as a technique of improving the resolution of the objective lens. A known technique thereof is interposing a liquid to increase the refractive index of the medium between the objective lens and the sample. Liquid immersion type microscopes have been commercialized as optical apparatuses that use this technique. The focusing of liquid immersion type microscopes with respect to a sample involves nothing more than performing adjustment visually, and means for automatically focusing have not been established.

In the case of microscopes, adjustment is performed visually, and no obstructions are produced, but high accuracy and high speed automatic focusing is in demand particularly in exposure apparatuses used in manufacturing processes such as those of semiconductor integrated circuits (hereunder, referred to simply as exposure apparatuses).

In addition, with existing liquid immersion type microscopes, there have been drawbacks in that easy removal of bubbles that have adhered to the front end of the objective lens is problematic, and the resolving power of the optical system decreases.

The purpose of the present invention is to provide, in an optical apparatus for observing a sample in a liquid or projecting a pattern to a sample, an apparatus that performs positioning and holding of the sample at that focus position automatically and with high accuracy while making it possible to easily remove bubbles that have adhered to the objective lens.

The inventors of the present application have developed a means of immersing a sample to increase resolving power in exposure apparatuses and have already applied for a patent (Patent Application No. 56-37977). In addition, a means for improving resolving power in detecting a pattern on a sample has been developed, and a patent application (Patent Application No. 57-84784) has been made. An apparatus that automatically focuses a large diameter lens (objective lens) used in these liquid immersion type exposure apparatuses is needed, and the present invention has been devised to resolve this.

The present invention will be explained in detail below using embodiments.

FIG. 1 is a drawing that explains the configuration of an embodiment of an apparatus of the present invention. In the drawing, 1 is an optical member (objective lens) of the optical apparatus (exposure apparatus), 2 is a lens barrel, 3 is a detector provided at the lower end of the lens barrel 2, 4 is a liquid suction hole, 5 is a pressure detection hole provided on the detector 3, 6 is the liquid for immersion, 7 is a sample, 8 is a sample platform that includes a drive apparatus, 9 is a piezoelectric transducer that converts the detected pressure to electrical signals and outputs them, 10 is an amplification control circuit, 11 is a liquid suction source, 12, 13 and 14 are restrictors that adjust the flow rate of the liquid, 15 is a liquid reservoir, 16 is a filter, 17 is a suction source for supply of the liquid 6, 18 is a filter, and 19 is an opening part of the detector 3.

The detector 3 is made to be nearly the same shape as the space formed in the optical path between the objective lens or the optical member 1 of the exposure apparatus and the sample 7, and it is connected to the lower end of the lens barrel 2. Note that the reason that the structure of the detector 3 is made nearly the same as that of the optical path of the optical system is to improve the response characteristic when controlling the position of the sample platform. The objective lens used in a common exposure apparatus is large with an aperture diameter of 30 mm ϕ or more and an image forming area of 15 mm ϕ or more, and a truncated cone shaped space defined by these two diameters becomes the optical path, which takes up considerable volume. The response characteristic is improved by keeping this volume to a necessary minimum.

The sample 7 is secured onto a sample platform 8 that is able to move in the optical axis direction of the optical system, and the surface of the sample 7, which has been coated with a photosensitive material, is covered by a liquid 6 for liquid immersion.

For the structure of the sample platform 8, it is possible to use a well known moving mechanism that is able to move in the optical axis direction.

A suction hole 4 is provided at the upper corner of the detector 3, and it is connected to a suction source 11 via a restrictor 12, which is a flow rate resistance element, via a pipe. Here, when the suction source 11 is operated, the interior of the detector 3 comes to have negative pressure, and the liquid 6 flows in from the opening part 19 of

the detector. The liquid that has flowed in is sent to the liquid reservoir 15 via the suction source 11 and filter 16. When the suction source 11 is operated at a constant pressure, the pressure of the interior of the detector 3 changes according to the size of the interval h of the detector 3 and the sample 7. For example, when the interval h becomes small, the absolute value of the negative pressure value inside the detector 3 becomes large. Conversely, when the interval h becomes large, the absolute value of the negative pressure value becomes small. In this way, the pressure of the interior of the detector 3 corresponds to the interval h . A pressure detection hole 5 is provided on the detector 3, and it is connected to the piezoelectric transducer 9 by means of a pipe. The piezoelectric transducer 9 converts pressure to electrical signals and is connected to a drive system attached to the sample platform 8 via the amplification control circuit 10. The amplification control circuit 10 drives the sample platform 8 so that the output of the piezoelectric transducer 9 becomes constant, specifically, so that the pressure within the detector 3 (that is, the interval h) becomes a constant value.

On the other hand, when the suction pressure of the suction source 11 fluctuates, the detection pressure within the detector 3 also fluctuates, and malfunction occurs as if the interval h has changed. To eliminate this kind of pressure fluctuation of the suction source, a reference unit is provided in the control system of this embodiment. The reference unit is configured to comprise a restrictor 14 that has a flow rate resistance that is equivalent to the flow rate resistance formed in the interval of the opening part 19 of the detector 3 and the sample 7 and a restrictor 13 that is equivalent to restrictor 12, and it is connected to the suction source 11. One end of restrictor 14 immerses that opening part in the liquid of the liquid reservoir 15, and the pressure between the other end of restrictor 14 and restrictor 13 is connected to the piezoelectric transducer 9 as a reference pressure via a pipe. The other end of restrictor 13 is connected to the suction source 11. Since the reference unit and the detector have the same suction source, pressure fluctuation of the suction source 11 is equivalently transferred, so fluctuation with respect to the pressure differential of the detection pressure and the reference pressure is eliminated. In this case, the piezoelectric transducer 9 electrically converts this pressure differential of the detection pressure and the reference pressure. In addition, the amplification control circuit 10 drives and controls the sample platform 8 so that the output value from the piezoelectric transducer 9, that is, the pressure differential, becomes constant. When a system of controlling the constant pressure differential of the detection pressure and the reference pressure so that it becomes zero is adopted, it becomes easy to correct the drift of the amplification control circuit 10. Specifically, the circuit should be corrected so that the output of the amplification control circuit 10 becomes zero in a status in which the suction source 11 is not operated.

In addition, when it is made possible to apply a constant voltage to the amplification control circuit 10 by means of an external circuit, it is also possible to provide the desired offset to the position of the sample platform. Details on the above two circuits are discussed in, for example, Utility Model Application No. 56-181162 applied for by the inventors of this application, and they can be applied to the present invention in the same way.

The liquid 6 on the sample 7 is supplied in an appropriate amount via an appropriate suction source 17 and filter 18 from the liquid reservoir 15, and this is done in a status such that the front end of the detector 3 is immersed.

In an apparatus of the present invention that is configured and operates as discussed above, autofocusing becomes possible by setting the interval h only one time so that the surface of the sample comes to the focus position of the optical system of the liquid immersion type exposure apparatus.

A feature in implementing the present invention is that the liquid is sucked in from the opening part 19 of the detector 3. This is because this is extremely effective in removing bubbles that have adhered within the detector 3 and to the lower part of the optical member 1. Even in a method substituting the suction source 11 with a supply source and expelling the liquid from the detector, pressure that corresponds to the interval h can be detected, but the use of a suction source is desirable for removing bubbles produced in the detector. Therefore, it is necessary to perform suction so that disturbance of the optical path by the bubbles is eliminated in such cases as when the optical member is at the top as in the embodiment, that is, in the case of a structure in which there is blockage by bubbles that have occurred in the liquid.

In this embodiment, in the case of an opening part 19 of the detector with a diameter of $6\text{ mm}\phi$ and an interval h of $250\text{ }\mu\text{m}$, H_2O is used as the liquid, and $2.5\text{ mmAq}/\mu\text{m}$ is obtained as the detection sensitivity of the position of the sample at a detection pressure of -1200 mmAq (gauge pressure) and a flow rate of 0.6 l/min . In cases where there is this detection sensitivity, it has been found that positioning and holding of the sample at an accuracy of approximately $\pm 0.1\text{ }\mu\text{m}$ is automatically possible.

Note that the data values indicated in the above embodiment are nothing more than examples, and it is thought to be easy to appropriately change them according to the viscosity of the liquid and the dimensions of the optical path of the objective lens.

In addition, the apparatus of the present invention is able to circulate liquid for liquid immersion, so it is also capable of filtering and temperature regulation of the liquid for liquid immersion and switching and supplying of two or more types of liquid.

In addition, the apparatus of the present invention can, of course, be broadly applied to not only exposure apparatuses but to apparatuses that require highly accurate positioning and holding of a distance in a liquid.

As explained above, for the apparatus of the present invention, in a liquid immersion type optical apparatus, it is possible to position and hold the position of the sample automatically and with high accuracy at the prescribed focus position of the optical system, and it is possible to easily remove bubbles that have adhered to the objective lens, so it is possible to prevent a decrease in the resolving power of the optical system.

4. Brief Explanation of the Drawings

FIG. 1 is a drawing that explains the configuration of an embodiment of the apparatus of the present invention.

- 1 optical member (objective lens)
- 2 lens barrel
- 3 detector
- 4 liquid suction hole
- 5 pressure detection hole
- 6 liquid for liquid immersion
- 7 sample
- 8 sample platform
- 9 piezoelectric transducer
- 10 amplification control circuit
- 11 suction source
- 12, 13, 14 restrictor
- 15 liquid reservoir
- 16 filter
- 17 suction source for liquid supply
- 18 filter
- 19 opening part of detector

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